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The Effects of Bioactive Edible Film containing *Terminalia arjuna* on the Stability of Some Quality Attributes of Chevon Sausages

Terminalia arjuna Incorporated Edible Film for Muscle Quality

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Abstract

The aim of this study was to assess the effectiveness of calcium alginate edible films incorporated with *Terminalia arjuna* on the lipid oxidative stability and storage quality of chevon sausages. Chevon sausages were aerobically packaged in the edible films containing different concentrations of *T. arjuna* viz. T_1 (0.0%), T_2 (0.50%) and T_3 (1.0%) and were stored under refrigerated (4 ± 1^0C) conditions. A significant improvement was observed in the lipid oxidative stability and microbial quality of the products. Products packaged in T_2 and T_3 films exhibited significantly ($P < 0.05$) lower values for TBARS (mg malonaldehyde/kg), microbial counts (log cfu/g) and FFA (% oleic acid). Higher ($P < 0.05$) sensory scores were also observed for the products packaged in T_2 and T_3 films. This study shows that application of a bioactive edible film incorporated with *T. arjuna* is an effective strategy in retarding the lipid oxidation and storage changes in meat products.

Keywords: *Terminalia arjuna*; edible film; chevon sausages; lipid oxidation; storage quality

1. Introduction

During either processing and/or storage, lipid oxidation largely brings about reduction in quality of meat and meat products (Noor, Bhat, Kumar, & Mudiyanselage 2018; Prado et al., 2015). Both primary and secondary lipid oxidation products contribute to the changes in flavour, colour, and texture as well as decrease in nutritional quality (Vital et al., 2016). Natural compounds with antioxidant and antimicrobial properties can affect the rate of lipid oxidation and quality of meat products. Polyphenols, the most common group of plant secondary metabolites, have been proven to be effective against oxidative reactions and microbes in meat products (Zhang et al. 2017). This potentially can explain why plant extracts with antioxidant and antimicrobial properties and rich in polyphenols have been employed by recent workers to maintain the quality of meat and meat products (Vital et al., 2016). Further, negative consumer attitude and public perception towards synthetic food preservatives has generated an increased interest in the use of these naturally occurring molecules to control food spoilage (Vodnar, Pop, Dulf, & Socaciu, 2015; Calo, Crandall, O'Bryan, & Ricke, 2015). While substantial data exist in favour of use of polyphenols from tea, rosemary, thyme, sage and other herbs as antioxidants, interest in the antioxidant properties of polyphenols from *Terminalia arjuna* has recently emerged (Kalem, Bhat, Kumar, & Desai, 2017).

T. arjuna, commonly named as *Arjuna*, is a deciduous and ever green tree belonging to *Combretaceae* family (Debnath et al., 2013) which contains many pharmacologically active principles like alkaloids, triterpenoids, tannins, flavonoids, saponins and reducing sugars (Debnath et al., 2013). It possesses multiple medicinal properties such as antioxidant, antimicrobial, antifungal, antiarthritic, antidiabetic, cardioprotective, antidiarrheal, and hepatoprotective (Bodke, Sindhe, Gupta, & Manjunatha, 2013) and may be explored for its potential as a natural preservative in food industry. Hebbani, Reddy, & Nallanchakravarthula,

(2014) studied the antioxidant activity of *T. arjuna* bark and reported that the extract contained phenolic compounds like β-sitosterol, catechin, rutin and tannic acid and had antioxidant activity comparable to butylated hydroxyanisole and ascorbic acid. Javed et al. (2016) observed moderate antifungal properties of *T. arjuna* leaves against *Microsporm canis* and the fruit extract was reported to have good antibacterial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*.

Biomolecules from plant extracts, such as *T. arjuna*, may have a positive impact on lipid oxidation, colour stability, and antioxidant activity in meat products, however, they may adversely affect the sensorial characteristics at their effective concentrations and moreover higher processing temperatures may reduce their preservative potential (Noor, Bhat, Kumar, & Mudiyanselage 2018). To combat these problems, addition of plant extracts with antioxidant and antimicrobial properties to edible films has been recently suggested to produce the bioactive edible films that avoids the effects of lipid oxidation without compromising the sensorial quality of the products (Noor, Bhat, Kumar, & Mudiyanselage 2018; Lopez et al., 2017; Pineros-Hernandez, Medina-Jaramillo, Lopez-Cordoba, & Goyanes, 2017). There is a current trend in food industry focused at developing new innovative concepts and packaging films with preservative capabilities (Vodnar et al., 2015; Ge et al., 2015). Bioactive edible food packaging systems could improve the lipid oxidative stability and storage quality of meat products by reducing moisture loss, lipid oxidation, colour deterioration and microbial spoilage (Gallego, Gordon, Segovia, & Pablos, 2016; Arfat, Benjakul, Vongkamjan, Sumpavapol, & Yarnpakdee, 2015). Several bioactive edible films and coatings incorporated with natural plant extracts and molecules have been developed recently. Maltodextrin based calcium alginate edible films were developed by Noor, Bhat, Kumar, & Mudiyanselage (2018) by using an extract from *A. racemosus*. Gelatine based films and coatings were developed by Gallego, Gordon, Segovia, and Pablos (2016) by using extracts from *Caesalpinia decapetala* and *Caesalpinia spinosa*. A kafirin film was developed by Giteru et al. (2015) incorporated with citral and quercetin as natural molecules. Edible films were developed from strawberry puree with carvacrol and methyl cinnamate as natural preservatives (Peretto et al., 2014). Several biopolymer-based edible films have been developed by using different plant extracts and molecules as bioactive ingredients, however, no literature is available, to the best of our knowledge, about the use of *Terminalia arjuna* as a bioactive ingredient for development of edible and biodegradable films.

The application of natural antioxidants and antimicrobials to edible films in pre-cooked meat products is an innovative but poorly explored option that needs further comprehension (Akcan, Estevez, & Serdaroglu, 2017). Polyphenol-rich plant extracts, such as *T. arjuna*, are considered as potent additives for development of bioactive edible films to prevent lipid oxidation and the microbial spoilage (Pineros-Hernandez, Medina-Jaramillo, Lopez-Cordoba, & Goyanes, 2017). The objective of this study was to develop a novel calcium alginate based bioactive edible film incorporated with *T. arjuna* with high antioxidant and antimicrobial potential, and study its effects on lipid oxidative stability, microbial quality and sensory properties during refrigerated storage of chevon sausages used as a model system.

2. Materials and Methods

2.1. Meat

The goat meat was obtained from a local market and utilized in various experiments. The meat was manually deboned after removing all tendons and separable connective tissue and trimming the fat. The lean meat was frozen at -18±2 ºC within the polythene pouches and thawed at refrigeration temperature (4±1ºC) before use.

2.2. Spice, condiments and fat

The spice mixture was prepared in the laboratory and contained coriander 20%, cumin seed 15%, aniseed 12%, black pepper 10%, red chilli 8%, green cardamom 6%, cinnamon 6%, white pepper 5%, black cardamom 5%, degi mirch (*Capsicum annum*) 5%, bay leaves 2%, cloves 2%, mace 2% and nutmeg 2%. Condiments used were onion, garlic and ginger in a ratio of 3:2:1 and were ground in a grinder to the consistency of a fine paste. Refined soya bean oil was procured from local market and used in the emulsion preparation.

2.3. Method of preparation of calcium alginate edible film

Maltodextrin based calcium alginate edible films with 1.89 MPa of tensile strength and 3.4×10^{-2} (g/m s Pa) of water vapour permeability were developed by using the method of Koushki, Azizi, Kamaly, and Azizkhani (2015). To make a film, 45 g maltodextrin powder was mixed with 5 g sodium alginate and 20 g glycerol was added to this mixture and dissolved in 210 ml double distilled water. The mixture was blended for 10 minutes to get a homogenous solution and was stirred for 4 hours to remove trapped air. The mixture (50 ml) was poured on 30×20 cm plexiglass sheet coated with cellophane and was spread by a glass rod to make a uniform thin sheet. The sheets were dried for 48 hours under ambient conditions and removed from the cellophane and dipped in a solution (2.75 g $CaCl_2$ and 0.9 g carboxymethylcellulose in 49 ml water) for 30 minutes and allowed to dry for 24 hours under ambient conditions.

2.4. *Terminalia arjuna*

Commercially available *Terminalia arjuna* in the capsular form was procured from “The Himalaya Drug Company”. The edible films were prepared by incorporating different concentrations of *T. arjuna* viz. 0.0% (T_1, 0 mg per 100 g of film mixture), 0.5% (T_2, 500 mg per 100 g of film mixture) and 1.0% (T_3, 1000 mg per 100 g of film mixture).

2.5. Method of preparation of chevon sausages

Small chunks of meat (67.4%) were minced in a Sirman meat mincer with 6mm plate twice and blended with salt (1.75%), sodium nitrite (150 ppm) and sodium tripolyphosphate (0.3%) for 1.5 minute in a Sirman bowl chopper. Water (10%) was added in the form of crushed ice and blending continued for 1 minute which was followed by the addition of refined soya bean oil (9%) and continued for another 1 to 2 minutes. Thereafter, condiments (5%), spice mixture (2%) and other ingredients were added and further continued for 1 to 2 minutes to get the desired emulsion. The emulsion was filled into the artificial polyamide casings with the help of Sirman sausage filler. The raw sausages were cooked at a temperature of 140 ± 5^0C for a time of about 30 minutes in a hot air oven. The products were cooled, and each sausage was enclosed into the edible film and six sausages were packaged together in low density polyethylene pouches and stored under refrigerated conditions (4 ± 1^0C).

2.6. Analytical procedures

2.6.1. Physicochemical parameters

The pH of the products was measured as per the method of Keller, Skelley, and Acton (1974) using a digital pH meter. TBARS (mg malonaldehyde/kg) value was estimated according to Witte, Krause, and Bailey (1970) whereas the method of Koniecko (1979) was followed for FFA (% oleic acid) estimation. Procedure described by AOAC (2000) was used to measure the moisture content of the products using a hot air oven.

2.6.2. Microbiological characteristics

Various microbiological characteristics were determined viz. total plate count, psychrophilic count, coliform count and yeast and mould count as per the methods described by APHA (1984).

2.7. Sensory evaluation

A trained sensory panel of ten members aged between 25 and 45 years evaluated the products for various sensory parameters namely colour and appearance, flavour, juiciness, texture and overall acceptability. The panel members were selected from a pre-existing group of judges involved with research studies with meat and were scientists and postgraduate scholars. The members of the panel were well known with product terminology and descriptions and were trained as per the American Meat Science Association (1995) guidelines for four basic tastes i.e. recognition and threshold test and routine hedonic tests performed in the laboratory. The panellists were served 3-digit coded control and treatment samples in random order and the nature of experiments was explained to them without disclosing the identity of samples. Samples were served warm (40^{o}C) and water was given for oral rinsing between the samples to avoid carry-over effect. Panellists were asked to evaluate each sample based on standard 8-point hedonic scale from 1 to 8 (Keeton, 1983) for appearance and colour, flavour, juiciness, texture and overall acceptability where 8 = excellent, extra desirable, extra juicy, extra desirable, and extra acceptable and 1 = extremely poor, extremely undesirable, extremely dry, extremely undesirable, and extremely unacceptable. The sensory analysis was performed at day 0, day 7, day 14 and day 21 of storage. Thigh muscles from a single animal were used for making one batch of products used for sensory evaluation to avoid differences not related to packaging. The sensory evaluation was repeated three times using meat from three different animals (same breed, age and muscles) for three batches of the products at each storage interval. Sausages were cut into slices (1 cm thick) and two slices of each sample were served to the assessors in a white plastic recipient.

2.8. Statistical analysis

The data generated by repeating the experiments for different quality parameters were compiled and analysed using SPSS (version 16.0). The experiments were replicated thrice, and all the samples were analysed in duplicate (n=6). All data were reported as means ± standard error. Microbial populations were transformed into log values. A two-way ANOVA was performed for analysing the data and for testing significance of repetition as random term. The treatment (edible films) and time (storage days) were the fixed terms in the model. Duncan's multiple range tests, at the 0.05 level of significance, were used for comparing the means to find out the effect of treatment and storage period. Ten panellists (fixed effect) performed the sensory analysis in three independent sessions (random effect) (Snedecor, & Cochran, 1994).

3. Results and Discussion

The mean values of various physicochemical parameters of chevon sausages aerobically packaged in edible films containing different concentrations of *T. arjuna* viz. T_1 (0.0%), T_2 (0.5%) and T_3 (1.0%) are presented in Table 1.

3.1. Physicochemical parameters

3.1.1. Thiobarbituric acid reacting substances (TBARS) value

A significant effect of packaging was observed as the products enclosed in edible films incorporated with *T. arjuna* (T_2 and T_3) showed significantly ($P < 0.05$) lower TBARS values than control and T_1 on all intervals of storage. This might be attributed to the antioxidant properties of *T. arjuna* that has been reported to contain high amounts of bioactive phytochemicals like polyphenols and flavonoids (Chatha, Hussain, Asad, Majeed, & Aslam, 2014). Similar results were reported by Gallego, Gordon, Segovia, and Pablos (2016) who observed significantly lower TBARS values for ground beef patties packaged in gelatine based edible films containing *Caesalpinia decapetala* and *Caesalpinia spinosa* plant extracts.

3.1.2. Free fatty acids (% oleic acid)

A significant effect of packaging was observed on free fatty acids (FFA) as the products wrapped in *T. arjuna* incorporated edible films (T_2 and T_3) showed significantly ($P < 0.05$) lower values than control and T_1 on all intervals of storage except day 0. This might be attributed to the antimicrobial properties of *T. arjuna* (Chatha, Hussain, Asad, Majeed, & Aslam, 2014; Debnath et al., 2013). Noor, Bhat, Kumar, & Mudiyanselage (2018) reported a similar effect of edible films incorporated with *A. racemosus* on FFA values of chevon sausages.

3.1.3. Moisture (%) and pH

A significant ($P < 0.05$) effect of the film was observed as the products packaged in edible films (T_1, T_2 and T_3) had higher moisture content than control. Edible films and coatings have been reported to improve the gas and moisture barriers of various products (Pascall, & Lin, 2013). pH of all the products showed a significant ($P < 0.05$) increase with storage and no effect ($P > 0.05$) of the edible film was observed. Noor, Bhat, Kumar, & Mudiyanselage (2018) also reported an increase in the pH of the chevon sausages wrapped in calcium alginate edible films during storage.

3.2. Microbiological characters

The mean values of various microbiological characteristics of chevon sausages packaged aerobically in edible films containing different concentrations of *T. arjuna* viz. T_1 (0.0%), T_2 (0.5%) and T_3 (1.0%) are presented in Table 2. Significantly ($P < 0.05$) lower total plate counts and psychrophilic counts were recorded for the products packaged in T_2 and T_3 edible films on all intervals of storage and might be attributed to the antimicrobial properties of *T. arjuna* (Chatha, Hussain, Asad, Majeed, & Aslam, 2014; Debnath et al., 2013). Antimicrobial activity of *T. arjuna* extract has been reported against various pathogenic and spoilage bacteria like *Enterococcus faecalis, Staphylococcus saprophyticus, Staphylococcus aureus, Proteus vulgaris, Proteus mirabilis, Acinetobacter baumannii, Citrobacter freundii, Escherichia coli, Acinetobacter sp., and Pseudomonas aeruginosa* (Debnath et al. 2013; Aneja, Sharma, & Joshi, 2012). Noor, Bhat, Kumar, & Mudiyanselage (2018) observed significantly ($P < 0.05$) lower total plate counts and psychrophilic counts for chevon sausages enclosed in calcium alginate edible films incorporated with *A. racemosus*.

Significantly ($P < 0.05$) lower yeast and mould counts were observed for the products packaged in *T. arjuna* incorporated edible films (T_2 and T_3). *T. arjuna* has been reported to have antifungal activity against several *Candida* species including *Candida albicans* (Debnath et al., 2013; Aneja et al., 2012). Moreira, Pereda, Marcovich, and Roura (2011) reported potentially strong antimicrobial action of bioactive packaging materials developed from edible chitosan and casein polymers on yeast and mould counts of cheese and salami.

Coliforms were not detected in any of the samples during entire period of storage which could be attributed to their destruction during cooking at 140°C. Several workers have reported zero counts for the meat products cooked at such a high temperature (Malav, Sharma, Kumar, & Talukder, 2015; Singh, Kumar, Bhat, & Kumar, 2015).

3.3. Sensory-associated parameters

The mean values of various sensory-associated characteristics of chevon sausages packaged aerobically in edible films containing different concentrations of *T. arjuna* viz. T_1 (0.0%), T_2 (0.5%) and T_3 (1.0%) are presented in Table 3.

3.3.1. Colour and texture

Packaging produced palpable effects on colour and appearance of the studied products as significant ($P < 0.05$) higher scores were recorded for sausages packaged in T_2 and T_3 edible films on all days of storage (except day 0). This might be attributed to the compounds of *T. arjuna* having strong antioxidant properties (Debnath et al., 2013; Nema et al., 2012). Interaction between lipid oxidative processes and discoloration in meat seem well established (Faustman, Sun, Mancini, & Suman, 2010). Vital et al. (2016) observed a significant improvement in the colour of beef steaks packaged in edible coatings with rosemary and oregano essential oils. A significant ($P < 0.05$) effect of the film was also observed on texture of the products. Significant ($P < 0.05$) higher scores for the sausages packaged in T_2 and T_3 edible films on day 7 and onwards could be due to antimicrobial and antioxidant properties of *T. arjuna* (Chatha, Hussain, Asad, Majeed, & Aslam, 2014; Debnath et al., 2013; Nema et al., 2012). Similar results were reported by Chatli et al. (2014) who observed significantly higher texture scores for chevon chunks wrapped in bioactive films impregnated with nisin and cinnamaldehyde.

3.3.2. Juiciness, flavour and overall acceptability

Packaging film also produced palpable effects on juiciness of the studied products. Significant ($P < 0.05$) higher scores were recorded for the products packaged in edible films (except day 0) which might be due to barrier properties of the edible films believed to improve the gas and moisture barriers (Pascall, & Lin, 2013).

Significant ($P < 0.05$) higher scores were recorded for flavour and overall acceptability for the products packaged in T_2 and T_3 edible films which might be attributed to the constituents of *T. arjuna* having strong antioxidant and antimicrobial properties (Chatha, Hussain, Asad, Majeed, & Aslam, 2014; Debnath et al., 2013; Nema et al., 2012). Bitter compounds can be produced during lipid oxidative processes, lipolysis and proteolysis and such occurrence have been reported to affect the flavour of meat products during storage (Mahajan, Bhat, & Kumar, 2015). Higher overall acceptability scores of the products might be reflective of other sensory parameters like colour, flavour, juiciness and texture. Significant higher scores were observed by Noor, Bhat, Kumar, & Mudiyanselage (2018) and Chatli et al. (2014) for flavour and overall acceptability of meat products wrapped in bioactive edible films.

4. Conclusions

T. arjuna, when incorporated into maltodextrin-based calcium alginate edible films, resulted in significantly (P < 0.05) lowered microbial counts, TBARS and FFA values, indicating that application of these bioactive films on the surface of meat products may control lipid oxidation and storage changes in meat products without compromising the sensorial quality. The results support that the use of these films as packaging material may have the potential to extend the shelf life of oxidation-susceptible fat-rich meat products such as cooked chevon sausages. It was concluded that extract of *T. arjuna* could be successfully added to calcium alginate edible films to function as natural bioactive ingredient, adding antioxidant and antimicrobial properties to the developed films. As promising as these results are additional research will be required to increase the level of addition. Future studies should focus on the use of *T. arjuna* as a bioactive ingredient for other packaging materials and systems as well as in different meat products.

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Table-1: Effect of *Terminalia arjuna* incorporated calcium alginate edible film on the physicochemical properties of aerobically packaged chevon sausages during refrigerated storage

Treatments	STORAGE PERIOD (DAYS)			
	0	7	14	21
TBARS (mg malonaldehyde/kg)				
Control	0.37 ± 0.03^{Ad}	0.53 ± 0.05^{Ac}	0.76 ± 0.04^{Ab}	1.26 ± 0.06^{Aa}
T_1 (0.0%)	0.28 ± 0.04^{ABd}	0.41 ± 0.04^{Ac}	0.63 ± 0.02^{Bb}	1.03 ± 0.01^{Ba}
T_2 (0.5%)	0.19 ± 0.05^{BCc}	0.25 ± 0.05^{Bc}	0.43 ± 0.05^{Cb}	0.82 ± 0.06^{Ca}
T_3 (1.0%)	0.10 ± 0.03^{Cb}	0.16 ± 0.03^{Bb}	0.20 ± 0.04^{Db}	0.62 ± 0.09^{Da}
FFA (% Oleic acid)				
Control	0.138 ± 0.018^{Ad}	0.193 ± 0.002^{Ac}	0.286 ± 0.024^{Ab}	0.446 ± 0.006^{Aa}
T_1 (0.0%)	0.123 ± 0.004^{ABd}	0.181 ± 0.011^{ABc}	0.262 ± 0.010^{ABb}	0.440 ± 0.013^{Aa}
T_2 (0.5%)	0.112 ± 0.003^{ABd}	0.153 ± 0.013^{Bc}	0.241 ± 0.008^{BCb}	0.412 ± 0.008^{Ba}
T_3 (1.0%)	0.101 ± 0.004^{Bd}	0.121 ± 0.007^{Cc}	0.210 ± 0.004^{Cb}	0.386 ± 0.004^{Ba}
Moisture (%)				
Control	64.26 ± 0.04^{Ba}	63.15 ± 0.03^{Bb}	62.08 ± 0.02^{Bc}	60.15 ± 0.02^{Bd}
T_1 (0.0%)	64.33 ± 0.05^{ABa}	63.29 ± 0.04^{ABb}	62.15 ± 0.03^{ABc}	60.21 ± 0.05^{ABd}
T_2 (0.5%)	64.41 ± 0.06^{ABa}	63.35 ± 0.04^{Ab}	62.20 ± 0.03^{ABc}	60.26 ± 0.04^{ABd}
T_3 (1.0%)	64.53 ± 0.11^{Aa}	63.42 ± 0.09^{Ab}	62.26 ± 0.09^{Ac}	60.38 ± 0.08^{Ad}
pH				
Control	6.29 ± 0.02^{c}	6.41 ± 0.02^{c}	6.56 ± 0.07^{b}	6.77 ± 0.02^{a}
T_1 (0.0%)	6.26 ± 0.04^{c}	6.38 ± 0.04^{c}	6.53 ± 0.04^{b}	6.73 ± 0.03^{a}
T_2 (0.5%)	6.21 ± 0.04^{d}	6.35 ± 0.03^{c}	6.49 ± 0.01^{b}	6.69 ± 0.02^{a}
T_3 (1.0%)	6.18 ± 0.02^{d}	6.32 ± 0.01^{c}	6.45 ± 0.01^{b}	6.65 ± 0.06^{a}

Means with different superscripts in a row wise (lower case alphabet) and column wise (upper case alphabet) differ significantly ($P < 0.05$)
T_1 (0.0%) = Sausages packaged in edible film containing 0.0% of *Terminalia arjuna*
T_2 (0.5%) = Sausages packaged in edible film containing 0.5% of *Terminalia arjuna*
T_3 (1.0%) = Sausages packaged in edible film containing 1.0% of *Terminalia arjuna*

Table-2: Effect of *Terminalia arjuna* incorporated calcium alginate edible film on the microbiological characteristics of aerobically packaged chevon sausages during refrigerated storage

Treatments	STORAGE PERIOD (DAYS)			
	0	7	14	21
Total plate count (log cfu/g)				
Control	1.73 ± 0.05^{Ad}	2.84 ± 0.02^{Ac}	3.75 ± 0.06^{Ab}	4.92 ± 0.02^{Aa}
T_1 (0.0%)	1.54 ± 0.06^{Bd}	2.63 ± 0.08^{Bc}	3.62 ± 0.03^{Ab}	4.73 ± 0.03^{Ba}
T_2 (0.5%)	1.39 ± 0.06^{Bd}	2.41 ± 0.09^{Cc}	3.41 ± 0.06^{Bb}	4.51 ± 0.08^{Ca}
T_3 (1.0%)	1.22 ± 0.04^{Cd}	2.18 ± 0.05^{Dc}	3.20 ± 0.06^{Cb}	4.21 ± 0.01^{Da}
Psychrophilic count (log cfu/g)				
Control	ND	ND	1.53 ± 0.06^{Ab}	2.79 ± 0.03^{Aa}
T_1 (0.0%)	ND	ND	1.42 ± 0.05^{Ab}	2.63 ± 0.06^{Aa}
T_2 (0.5%)	ND	ND	1.21 ± 0.02^{Bb}	2.42 ± 0.06^{Ba}
T_3 (1.0%)	ND	ND	1.09 ± 0.02^{Bb}	2.15 ± 0.04^{Ca}
Coliform count (log cfu/g)				
Control	ND	ND	ND	ND
T_1 (0.0%)	ND	ND	ND	ND
T_2 (0.5%)	ND	ND	ND	ND
T_3 (1.0%)	ND	ND	ND	ND
Yeast and mould count (log cfu/g)				
Control	ND	ND	1.82 ± 0.04^{Ab}	2.67 ± 0.03^{Aa}
T_1 (0.0%)	ND	ND	1.75 ± 0.07^{ABb}	2.47 ± 0.05^{Ba}
T_2 (0.5%)	ND	ND	1.61 ± 0.04^{Bb}	2.31 ± 0.06^{Ba}
T_3 (1.0%)	ND	ND	1.37 ± 0.03^{Cb}	2.15 ± 0.05^{Ca}

Means with different superscripts in a row wise (lower case alphabet) and column wise (upper case alphabet) differ significantly ($P < 0.05$)
T_1 (0.0%) = Sausages packaged in edible film containing 0.0% of *Terminalia arjuna*
T_2 (0.5%) = Sausages packaged in edible film containing 0.5% of *Terminalia arjuna*
T_3 (1.0%) = Sausages packaged in edible film containing 1.0% of *Terminalia arjuna*
ND = Not Detected

Table-3: Effect of *Terminalia arjuna* incorporated calcium alginate edible film on the sensory characteristics of aerobically packaged chevon sausages during refrigerated storage

Treatments	STORAGE PERIOD (DAYS)			
	0	7	14	21
Colour and Appearance				
Control	7.05 ± 0.12^{a}	6.22 ± 0.07^{Ab}	5.14 ± 0.14^{Dc}	4.26 ± 0.14^{Cd}
T1 (0.0%)	7.11 ± 0.15^{a}	6.45 ± 0.04^{Ab}	5.62 ± 0.11^{Cb}	4.46 ± 0.12^{Cc}
T2 (0.5%)	7.14 ± 0.12^{a}	6.76 ± 0.11^{Bb}	5.98 ± 0.08^{Bc}	4.97 ± 0.10^{Bd}
T3 (1.0%)	7.17 ± 0.08^{a}	6.92 ± 0.11^{Ba}	6.43 ± 0.11^{Ab}	5.79 ± 0.17^{Ac}
Flavour				
Control	7.48 ± 0.07^{a}	6.32 ± 0.20^{Bb}	5.15 ± 0.09^{Dc}	4.18 ± 0.11^{Cd}
T1 (0.0%)	7.40 ± 0.11^{a}	6.63 ± 0.14^{ABb}	5.56 ± 0.10^{Cc}	4.43 ± 0.11^{Cd}
T2 (0.5%)	7.36 ± 0.09^{a}	6.98 ± 0.12^{Ab}	5.87 ± 0.11^{Bc}	4.92 ± 0.13^{Bd}
T3 (1.0%)	7.29 ± 0.07^{a}	7.01 ± 0.10^{Ab}	6.47 ± 0.05^{Ac}	5.72 ± 0.10^{Ad}
Juiciness				
Control	7.16 ± 0.14^{a}	6.62 ± 0.11^{Bb}	6.43 ± 0.13^{Bb}	5.53 ± 0.10^{Bc}
T1 (0.0%)	7.22 ± 0.10^{a}	6.76 ± 0.14^{ABb}	6.57 ± 0.10^{ABb}	5.81 ± 0.13^{ABc}
T2 (0.5%)	7.25 ± 0.13^{a}	6.89 ± 0.08^{ABb}	6.76 ± 0.11^{ABb}	5.87 ± 0.09^{ABc}
T3 (1.0%)	7.31 ± 0.06^{a}	6.97 ± 0.09^{Ab}	6.87 ± 0.13^{Ab}	5.96 ± 0.16^{Ac}
Texture				
Control	7.21 ± 0.10^{a}	6.36 ± 0.07^{Bb}	5.85 ± 0.13^{Dc}	5.24 ± 0.13^{Cd}
T1 (0.0%)	7.25 ± 0.15^{a}	6.47 ± 0.07^{Bb}	6.19 ± 0.08^{Cb}	5.52 ± 0.11^{Cc}
T2 (0.5%)	7.29 ± 0.13^{a}	6.69 ± 0.07^{Ab}	6.51 ± 0.08^{Bb}	5.96 ± 0.12^{Bc}
T3 (1.0%)	7.35 ± 0.06^{a}	6.92 ± 0.09^{Ab}	6.83 ± 0.12^{Ab}	6.43 ± 0.16^{Ac}
Overall Acceptability				
Control	7.37 ± 0.09^{a}	6.13 ± 0.07^{Cb}	5.19 ± 0.10^{Dc}	4.32 ± 0.12^{Cd}
T1 (0.0%)	7.30 ± 0.06^{a}	6.37 ± 0.14^{Cb}	5.61 ± 0.14^{Cc}	4.53 ± 0.08^{BCd}
T2 (0.5%)	7.26 ± 0.10^{a}	6.68 ± 0.13^{ABb}	5.97 ± 0.14^{Bc}	4.94 ± 0.19^{Bd}
T3 (1.0%)	7.19 ± 0.06^{a}	6.95 ± 0.09^{Aa}	6.51 ± 0.08^{Ab}	5.82 ± 0.15^{Ac}

Means with different superscripts in a row wise (lower case alphabet) and column wise (upper case alphabet) differ significantly ($P < 0.05$)

T_1 (0.0%) = Sausages packaged in edible film containing 0.0% of *Terminalia arjuna*

T_2 (0.5%) = Sausages packaged in edible film containing 0.5% of *Terminalia arjuna*

T_3 (1.0%) = Sausages packaged in edible film containing 1.0% of *Terminalia arjuna*

Highlights

- A novel calcium alginate edible film incorporated with *Terminalia arjuna* was developed
- Developed films had significant antimicrobial and antioxidant properties
- The developed films improved the lipid oxidative stability of the model meat product
- A significant improvement was also observed in the microbial and sensory quality